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Metal concentrations in the shell of *Bathymodiolus azoricus* from contrasting hydrothermal vent fields on the mid-Atlantic ridge

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Abstract

Specimens of *Bathymodiolus azoricus* were sampled along the Mid-Atlantic Ridge at the Menez Gwen, Lucky Strike and Rainbow hydrothermal fields. Individual shells ($n = 51$), through the weight range 0.62 to 15.70 g, were analyzed for their magnesium, strontium, iron, manganese, copper, zinc and cadmium concentrations. Amongst the marine molluscs the shell of *B. azoricus* is confirmed as being particularly impoverished in strontium (mean 943 $\mu g\ g^{-1}$). Trace metal concentrations in the shells decreased in the order Fe > Mn > Zn > Cu > Cd. Despite originating from trace metal rich environments mean concentrations were low (37.9, 13.2, 10.7, 1.1 and 0.7 $\mu g\ g^{-1}$, respectively). Irrespective of geographical origin magnesium, strontium and copper concentrations were primarily dictated by shell weight. In contrast cadmium concentrations were elevated in shells from the Rainbow field and ambient seawater chemistry imparted site specific chemical fingerprints to the shells with respect to the iron to manganese ratio.

Keywords: Metals; Shells; *Bathymodiolus azoricus*; Hydrothermal vent field; Menez Gwen; Lucky Strike; Rainbow

1. Introduction

To date seven extensive hydrothermal fields have been discovered along the Mid-Atlantic Ridge (MAR) between 14°N and 38°N. Since 1991 the area has been extensively surveyed with respect to both the chemical characteristics of the hydrothermal fluids and the associated biological fauna. Areas contiguous to the hydrothermal vents are highly productive (Rousse et al., 1997; Little and Vrijenhoek, 2003; van Dover and Lutz, 2004). Among the life forms bivalve molluscs are generally present in large numbers, particularly the mussel *Bathymodiolus azoricus* (van Dover et al., 1996; von Cosel et al., 1999; Colaço et al., 1998, 2002; Desbruyères et al., 2000, 2001).

Much attention has been given to the extent to which the high metal concentrations in hydrothermal areas accumulate in the soft tissues of the associated bivalves (Roesijadi and Crecelius, 1984; Roesijadi et al., 1985; Smith and Flegal, 1989; Geret et al., 1998; Rousse et al., 1998; Company et al., 2004, 2006; Hardivillier et al., 2004; Bebianno et al., 2005; Colaço et al., 2006; Kádár et al., 2006a, 2006b, 2007). In contrast there are few data on the extent to which the high environmental trace metal concentrations influence the chemical assemblage in the shell (Roesijadi and Crecelius, 1984; Roesijadi et al., 1985; Kádár and Costa, 2006; Cravo et al., 2007).

Mineralisation of skeletal carbonates involves the deposition of calcium carbonate in the form of calcite and/or aragonite. The minor elements, magnesium and strontium, together with the trace metals are incorporated into the carbonate crystal lattice of the shell by diadochically replacing the calcium ions in the calcite and aragonite (Deer et al., 1966).

Roesijadi and Crecelius (1984) and Roesijadi et al. (1985) were the first authors to report on the chemical composition of shells taken from hydrothermal areas. They

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presented data on the trace metal concentrations in the shell of five specimens of the vent clam *Calyptogena magnifica* taken from the Oasis site (21°N, 109°W) on East Pacific Rise. The very low mean concentrations of Fe, Mn, Cu, Zn and Cd in these shells (17.4, <3, 5.9, 3.4 and 6.9 μg g^{-1}, respectively) lead the authors to conclude that, in contrast to the soft tissues of *Calyptogena magnifica*, its shell was not a site of metal accumulation or deposition. Kádár and Costa (2006) and Cravo et al. (2007) provided preliminary observations on the composition of the shell of *B. azoricus* taken from the MAR. Both these works provide valuable but limited information on the composition of the shell and its variability. In an inter-population study Kádár and Costa (2006) generated data on five individual shells taken from each of two contrasting hydrothermal sites along the ridge. Cravo et al. (2007) provided data on a greater number of individual shells but these were all from a single site. Interestingly the two works produced a dichotomy of opinion with respect to two key issues. Kádár and Costa (2006) reported high concentrations of trace metals in the shell (mean concentrations of iron, copper and zinc were 280, 80 and 40 μg g^{-1} respectively). In contrast Cravo et al. (2007) found that despite originating from a trace metal rich environment the trace metal concentrations in the shell of *B. azoricus* were exceptionally low, the mean concentrations of iron, copper and zinc being 20.6, 0.6 and 9.4 μg g^{-1}, respectively. The disparity with respect to the levels of trace metals can in part be explained by the different cleaning and analytical procedures adopted. Secondly, Kádár and Costa (2006) concluded that the shell of *B. azoricus* was a good monitor of environmental levels of iron, copper and zinc in waters contiguous to deep-sea hydrothermal vents. In contrast, Cravo et al. (2007) inferred that due to the low metal concentrations found the shell of *B. azoricus* had little potential use for trace metal monitoring in hydrothermal vent areas.

The present paper extends the observations of Kádár and Costa (2006) and Cravo et al. (2007) and provides the first comprehensive data on both the intra- and inter-population variability in the chemical composition of the crystal matrix of the shell of *B. azoricus* taken from contrasting hydrothermal fields along the MAR.

2. Study area

Samples of *B. azoricus* were taken from vent fields on the MAR in the vicinity of the Azores Triple Junction (Fig. 1). There are three major hydrothermal fields in the area, Menez Gwen, Lucky Strike and Rainbow. Menez Gwen (37°51′N, 31°31′W) is the northernmost and the shallowest of the three with a depth of 850 m (Company et al., 2004). To the south of Menez Gwen is Lucky Strike (37°17′–37°18′N, 32°16′–32°17′W). This field, discovered in 1992, is one of the largest known active fields on the MAR. It is deeper than Menez Gwen. Depths vary from 1630 to 1730 m (mean 1700 m, Charlou et al., 2000). The hydrothermal fields are distributed around 37°N and the discrete active venting sites are dispersed over an area about 700 m long and 300 m wide. To the southeast and the northwest the hydrothermal venting sites are distributed around a lava lake. Within this large hydrothermal area, samples of *B. azoricus* were taken from two locations. In the active zone to the northwest, samples were taken adjacent to Bairro Alto (37°17′34N, 32°17W). To the southeast of the lava lake further samples of *B. azoricus* were collected in proximity to Eiffel Tower (37°17″19N, 32°16′29W). Further south along the ridge from Lucky Strike is Rainbow (Fig. 1). Located at 36°13′N, 33°54′W and discovered in 1997 (Fouquet et al., 1997) this field is the deepest active segment of the Azores Triple Junction with water depths between 2270 and 2320 m (mean 2300 m, Charlou et al., 2002).

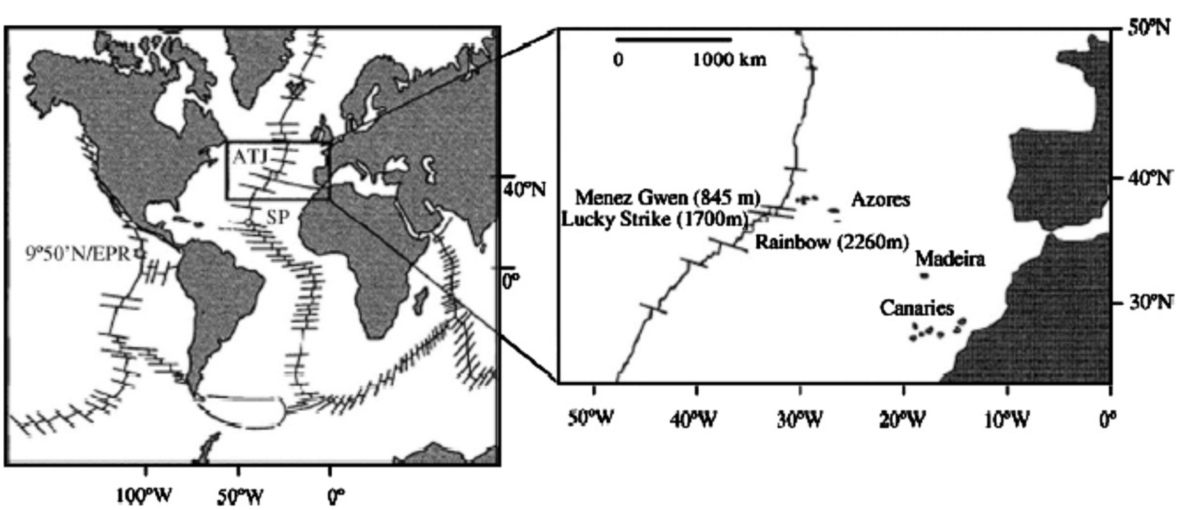

Fig. 1. Location of the Menez Gwen, Lucky Strike and Rainbow hydrothermal fields in the Azores Triple Junction (adapted from Comtet et al., 2000).